Explosives And Blasting Techniques In Mines

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EXPLOSIVES

Q. 1. *Write short notes on (a) Explosive (b) Low explosive (c) High explosive.*

Ans. (*a*) *Explosive* : An explosive is a substance which contains combustible ingredients and necessary oxygen for complete and rapid combustion. When an explosive is ignited or detonated, instantaneously it converts into volume of gases at very high temperature and great pressure.

Explosives are classified into two main classes (1) low explosive and (2) high explosive.

(*b*) *Low Explosive* : Low explosive is a mechanical mixture of finely ground combustible substances and suppliers of oxygen, it can be fired by ignition and it produces leaving effect. Its velocity of propagation of flame is low ; a few metres per second. Gunpowder is an example of this class of explosive. (Composition of gunpowder charcoal—15%, Sulphur—10%, Potassium Nitrate—75%)

(*c*) *High Explosive* : High explosive is a chemical compound and the chemical reaction is normally initiated in it by detonation. It has a shattering effect. Its velocity of detonation is a few kms. per sec., Nitro-cellulose, Nitro-glycerine, Ammonium nitrate etc are the chemical compounds used as high explosive and these compounds are substitution products of combustible substances like cellulose, glycerine, ammonia and nitric acid.

Q. 2. *Outline the essential composition of an explosive and in particular, mention any necessary ingredient to make the explosive suitable for use in coal mines.*

Ans. Essential composition of an explosive is a combustible substance and an oxidising agent. Common combustibles used are charcoal, cellulose, benzene, napthalene, glycerine etc. and common oxidising agents are nitric acid,

potassium nitrate, sodium nitrate, barium nitrate, ammonium nitrate, potassium chlorate, potassium perchlorate and ammonium perchlorate etc On the application of heat free oxygen is released from the oxidising agents and that oxygen combine with the constituents of the combustible substance. The explosive should be oxygen balanced to oxidise the carbon to carbon-dioxide and the hydrogen to water vapour otherwise poisonous gases like carbon monoxide and oxides of nitrogen will be produced.

To make an explosive suitable for use in coal mines some form of cooling of hot-gases is needed and sodium chloride, potassium chloride etc. are used for the same purpose.

Q. 3. *What are the requirements of an explosive for commercial use ?*

Ans. Various requirements are detailed below.

(*a*) *Sensitivity*—It must be sensitive enough so that it explodes positively when it is ignited or detonated but at the same time it should be so insensitive to detonation or ignition that it enables safe handling and transportation.

(*b*) *Chemical stability*—It should not decompose under heat.

(*c*) *Explosive strength*—Explosives of varying power are available depending on the job requirement. The strength is expressed both on the basis of unit volume and unit weight.

(*d*) *Velocity of detonation*—Coupled with the strength of an explosive, velocity of detonation contributes to the blasting effect. For example in hard rock explosives of high velocity of detonation (and high strength) are used while for mining coal and other soft material explosives with low velocity of detonation are used.

(*e*) *Fume*—When an explosive detonates it should not give rise to objectionable proportions of oxides of nitrogen and CO.

For the same the ingredients in the composition of an explosive must be properly adjusted so that oxygen in the explosive be balanced.

(*f*) *Waterproofness*—The explosives should have adequate water resistance so that they can be used in watery mines.

Gelatinous explosives are suitable for watery mines whereas powder explosives do not have water resistance and these are used in dry bore-holes.

(*g*) *Cost*—Cost of explosive should be low because overall economics of mining has a direct bearing on it.

Q. 4. *What are the major factors to be taken into consideration for use in mines ?*

Ans. The major factors to be taken into consideration may be enumerated.

(*a*) *Nature of the mine*—See whether the mine is opencast or underground. In case of opencast mines we may use liquid oxygen as an explosive and nonpermitted explosive, which are not permitted for use in underground mines.

(*b*) *Moisture and Water*—In moist atmospheres, and particularly in wet ground, the hygroscopic types of explosive such as some of the ammonium nitrates are unsuitable and a high-density water-resisting type of explosive should be chosen.

(*c*) *Oxygen Balance*—If the oxygen in the explosive is not balanced, poisonous gases like CO. and oxides of nitrogen are produced. So the explosives which have not balanced oxygen must not be used in underground mines.

(*d*) *Sensitivity*—The explosive should be safe to handle, but it must be sufficiently sensitive to ensure complete detonation in use.

(e) *Nature of the ground*—Where explosive have to be used in hard rock, a high density, bulk strength and velocity explosive should be selected. Powder type explosives are unsuitable for wet condition. For softer shale measures a weaker gelatine or an ammonium nitrate TNT powder may be used.

(f) *Other important factors*—to be considered for use in coal are nature of the coal, thickness of the seam, presence of cleavage, presence of hard band in the coal seam, grades of coal required, degree of gassiness of the coal seam.

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PERMITTED EXPLOSIVES

Q. 5. *Write short notes on : (a) Permitted explosive (b) Sheathe explosive (c) Equivalent sheathed explosive (d) Ultra-safe explosive.*

Ans. (a) All permitted explosives are high explosives which pass certain prescribed tests in the presence of fire-damp and coal dust in the test gallery of the Central Mining Research Station, Dhanbad, and are then permitted by the Director General of Mines Safety for use in gassy mines. They are also known as low-flame temperature explosives. The flame temperature is reduced and the duration of the flame produced is also reduced to the minimum, by suitable design of composition. The safety of the permitted explosives depends on the above two factors. A cooling agent is an essential constituent of a permitted explosive.

(b) The cartridges of these explosives are surrounded lengthwise by sheath of sodium bi-carbonate about 3 m.m. thick. The sodium bi-carbonate may be either in powder

form held in position by a paper wrapper, or preferably in the form of a felt, like thick blotting paper, secured to cartridges by adhesive composition. The sheath forms an extinctive blanket of CO_2 and H_2O around the detonating explosive and thus reduce the danger of igniting firedamp. Among the other advantages of these sheathed explosives, —they afford protection against breaks, they help to maintain the sensitiveness and efficiency of the explosive, reduced volume of noxious gas is produced and they produce more round coal, but larger diameter of shot holes are needed to use these explosives and chances of incomplete detonation remains if sheath gets in between two catridges. These explosives are not in use in our country now-a-days.

(c) In these explosives cooling agents are added directly and uniformly to the explosive composition itself. From the point of view of safety, these explosives are equivalent to the sheathed explosive, more over the dangers associated with sheathed explosives in case of displacement of sheath are eliminated.

(d) This explosive was designed on specific idea that this would not ignite methane-air-mixture under any condition of test, that is to give a greater safety than equivalent sheathed explosive. For the same, a high percentage of finely ground sodium chloride and nitro chalk were added in the composition of this explosive, but it was found that the sensitivity of the explosive to satisfy ultra-safe condition reduced the strength of the explosive to a impracticable limit and reduced its sensitivity to. So, search for general overall safety was abeyance and attempts to design explosives for specialised use started.

Q. 6. *Describe briefly, how the permitted explosives develop from P-1 to P-5 and name which of them are being used in our mines.*

Ans. From the first development of permitted explo-

sive (now classified as (P-1) several improvements have taken place to improve the safety of the permitted explosive. The latest developed permittd explosive is classified as P-5 explosive.

Essential characteristic of P-1 permitted explosive is incorporation of sodium chloride, as cooling agent in the composition of the explosive is considered to be completely safe in clean, well formed bore-holes, if fired accidently under less satisfactory conditions.

Second development is addition of sodium bicarbonate sheath around the explosive cartridge which is known as sheathed explosive and this explosive is classified as P-2 explosive. During the use of this explosive, it is found that the sheath comes out too frequently and thus the safety of the explosive is hampered.

Third development is incorporation of some cooling agents in the composition of the explosive itself. From the point of view of safety, this explosive is equivalent to the sheathed explosive and this explosive is classified as P-3 explosive. This explosive is also found not completely safe when fired in the presence of break in the coal seam and in unstemmed blown-out conditions which may occur in cut-off shots.

Further attempts are made to design an ultra-safe explosive, which will not ignite methane air mixture under any condition and finally an explosive for the same purpose is developed, but it is found that the power and sensitivity of the explosive is reduced to impracticable limit. So it is discontinued and attempts are made to design new explosives for specialised use. Ultimately an explosive known as "*Carrifax*" is designed far blasting in rippings to guard against ignition of firedamp in breaks, which is classified as P-4 explosive and another explosives for delay firing in solid coal known as '*Dynagax*' in U. K. and '*Soligex*' in our country are developed which are classified

as P-5 explosives. These explosives are safe in the event of blown out shot or when detonation takes place with the shot-hole cut off by a preceding shot.

Among the five types of permitted explosives, three types are being used in our mines presently—

P-1 type viz.	Viking G and Ajax G
P-3 type viz.	Unisax G
P-5 type viz.	Soligex.

Q 7. *What main precautions you will take when using permitted explosives in coal seam.*

Ans. The main precautions to be taken for using permitted explosives in coal seams are—

(*a*) The coal must be undercut, overcut or sidecut, or exemption must be asked from the D.G.M.S. for blasting in solid coal.

(*b*) The length of the shot-hole must be at least 15 cm. less than the depth of the cut.

(*c*) No detonator other than electric detonator with a copper tube shall be used.

(*d*) Where more than one shot are charged for firing the shots shall be fired simultaneously.

(*e*) The aggregate charge in any shots to be fired shall not exceed such permissible maximum charge, as the D.G.M.S. may, by a notification in the official Gazette, lay down for the kind of permitted explosives used.

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BLASTING ACCESSORIES

Q. 8. *Write short notes on: (a) Detonator (b) Exploder (c) Circuit tester (d) Shotfiring Cable (e) Scraper (f) Break detector (g) Cordtex (h) Stemming material (i) Water stemming.*

Ans. (*a*) *A detonator* is the means whereby the detonation of a high explosive is initiated. Essentially, it consists of a metal tube, which may be of copper or aluminium, and this tube contains the detonating compound. The tube of the detonator must be of copper, for use in gassy mine, as aluminium detonator are incendiary nature. The detonating compound is fitted with an electric fuse which "sets off" the detonator.

The detonators may be classified as—

(1) *Plain detonators* :—These are fired by safety fuse. The detonators explode by the spark from the fuse. These detonators are used in opencast mines only.

(2) *Ordinary electric detonators* :—These are fired by electric current from the shot-firing apparatus. They may be low tension, or high tension.

(3) *Delay detonators* :—These are low tension electric detonators, with delay element introduced between the fuse head and priming charge These are subdivided into two classes, (i) half second delay detonators, and (ii) millisecond delay detonators or shot delay detonators.

(*b*) *An exploder* is the apparatus for firing shots electrically. The exploder must be approved type, for use in mines. Essentially, the exploder consists of a source of electrical energy, which may be either magneto generator or a battery of dry primary cells. Both single shot and multi-shot exploders are in use for shot-firing.

'*Little Demon*' is the common type single-shot exploder normally in use in Indian coal mines. It is of magnetic

type and is operated by half-turn of a detachable firing key.

ME-6 Exploder is a battery-operated condensor-discharge type exploder designed to fire up to six electric detonators. The Schaffler 350 (25 shots) exploder and the Schaffler 351 (10 shots) exploder are approved exploder for use in all mines. For use in shaft sinking and stone drifting D.G.M.S. has approved "Beethoven" multi-shot exploder, subjected to certain conditions.

(*c*) *While practising multi-shot firing*, it is essential that the circuit should be tested for continuity and resistance before firing a round of shots. The apparatus by which these tests are carried out is known as 'circuit tester'. These tests should be done by an approved circuit tester and the current needs for the test should be limited, so that there is no possibility of accidental initiation of detonators. All such tests must be carried out from a safe place. The Gyro ohmmeter circuit tester is the only approved circuit tester by D. G. M. S.

(*d*) *As per Coal Mines Regulations, 1957, shot-firing cables* shall be well insulated and shall be of sufficient length which shall in no case be less than 18 m long. A few of the approved shot-firing cables are :—

(i) *2-core cable for single shot firing* :—

Each core consists of 4 copper wires not less than 0·018″ dia. insulated with vulcanised rubber or PVC 0·020″ thick with two cores twisted and covered with a sheath of cotton-braided tough rubber or PVC.

(ii) *Single core cable for multi-shots* :—It consists of conductor of 3 copper wires not less than 0·036″ dia. insulted to withstand at least 250 V and further protected against wear and damage.

(iii) *Two cable for shot firing in sinking shafts* :—Each core consists of seven copper wires, each not less than 0·029″ dia. insulated to withstand 250 V. It shall be

well protected and must support its own weight when suspended.

The shot firing cable should be handled carefully ; it should be hung on pillars or supports. In multi-shot firing, the two lengths of single core cable should be hung on either side of gallery to avoid short circuiting.

(*e*) *Scraper is used to clear shot holes of coal dust.* As per law, the scraper shall be made of brass or wood.

(*f*) It is a tool for detecting cracks in the shot hole.

The break detector shall be of approved type by the D.G.M S. for use in mine.

(*g*) *Cordtex is a detonating fuse* which consists of a core of a high explosive called PETN. This core is covered with textile covering which is completely enclosed in a tubular cover of white plastic material. Though cordtex has a high water resistance, even then ends must be kept suitably sealed. It is safe to handle and it will not deteriorate even after several years of storage. Its velocity of detonation is about 6000 m /sec. For detonating an explosive, the cordtex fuse must be in close contact with the explosive. The cordtex needs a detonator for initiating. The cordtex is used in opencast blasting and in pulsed infusion shot firing.

(*h*) *The stemming of shot hole* is needed to confine the explosive in the shot hole and thereby to help it to perform its act. Moreover it prevents blown-out shot, provides a safeguard against ignition of firedamp and coal dust explosion. Clay and sand mixed in proportion 1 : 3 and moistened with water sufficient to keep it in plastic form is the most convenient and effective stemming material for use in mines. Polythene bags filled with water are also used as an effective stemming material.

(*i*) In this method, *water in P.V.C. bags* is used as stemming material. The bags are about 0·5 m long and 31 mm dia. The bags may be self-sealing type or may be

of open ends. In case water is available in underground, the bags may be filled in underground. For charging a shot hole, a sand-clay plug of normal sand clay stemming material is first inserted in the shot hole, the explosive is then charged, one or two water filled bags are then inserted, finally the sand-clay stemming material is inserted upto to the mouth of the shot hole. A minimum length of 0·3 m of sand-clay stemming at the mouth of the shot hole is desirable. The method suppresses the dust and fumes during blasting, produces more round coal due to the cushioning effect, improves the blasting efficiency, moreover it needs no capital outlay.

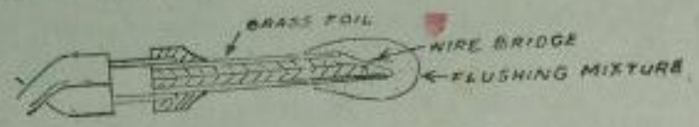
Q. 9. *Briefly describe an ordinary electric detonator. State the reason, why it should not be used as a substitute for delay detonator with zero delay.*

Ans. It consists of a copper or alumininm tube, 6 mm dia. and 37 to 50 mm long. Aluminium detonators are used in opencast mines. The tube contains two separate charges, namely—

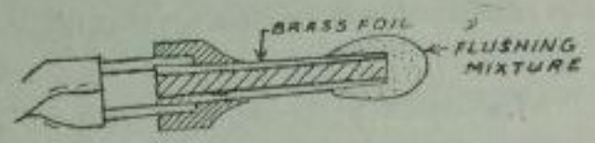
(*a*) a top or priming charge consisting of a mixture of lead azide and lead styphnate with a small percentage of aluminium powder, and

(*b*) a bottom or main charge of tetryl which acts as the detonating medium No. 6 detonators, which are generally used in mines, contain 0·35 gm priming charge and 0·25 gm main charge. In the upper half of the tube is an electric fuse consisting of a fuse-head which is connected to a pair of copper wires termed the 'leads', and is embeded in a neoprene plug. The fuse head may be either low tension or high tension The low tension fuse consists of two thin strips of brass foil, separated by a sheet of insulating material and are connected diagonally at the lower end by a fine wire of nickel chromium alloy, which is immersed in a bead of an inflammable flashing mixture consisting of the lead salt of

mono-nitro-resorcinal (known as L.M.N.R.), potassium chlorate, charcoal, and condition. The leading wires are soldered to the brass foils at the upper ends, so there is a continuous metallic circuit through the fuse. In case

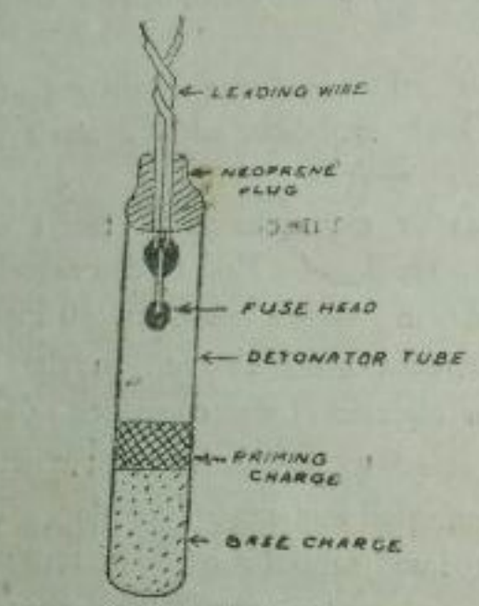


LOW TENSION FUSE



HIGH TENSION FUSE

of high-tension fuse no metallic bridge is inserted to join the two strips of brass foils and their cardboard supports are both of same length and are dipped into the



ORDINARY ELECTRIC DETONATOR

FIG. 1

same flashing mixture as before, except that copper acetylide mixed with graphite is incorporated to form a chemical bridge, across which the electric current sparks

when a sufficient high E M. F. is applied. The high tension detonators are not commonly used in mines.

The ordinary electric detonators should not be used as a substitute for zero delay detonator, because they may have some '*tolerance*' before detonation.

Q. 10. *Describe a delay action detonator. Explain for what purpose this type of detonator is used. State the additional precautions which are necessary for its use.*

Ans. A delay detonator is essentially a low tension detonator. Its priming charge and base charge are A. S. A. mixture and P. E. T. N. or tetryl as in case of low tension ordinary detonator. The fuse head construction is also

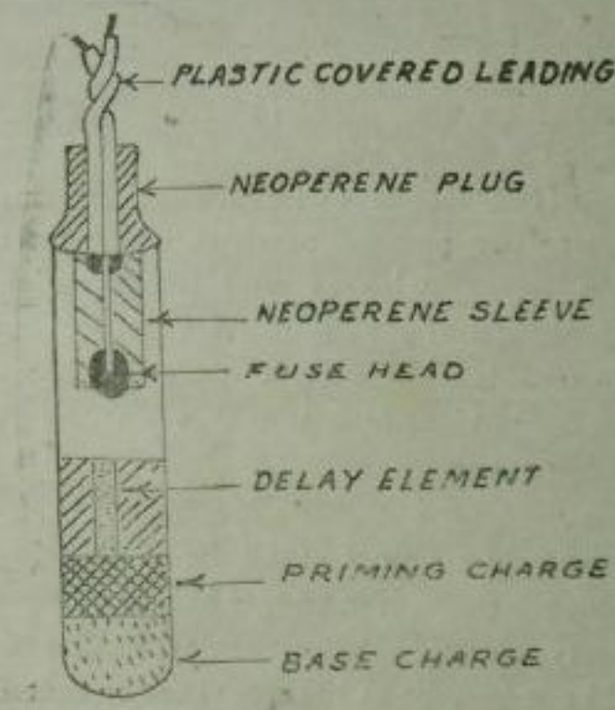


FIG. 2
DELAY DETONATOR

similar to the ordinary electric detonator, only difference is a delay element in a copper or brass sleeve is introduced between the fuse-head and the priming charge, in the construction to delay detonator. The delay elements, for

half second delay detonators is a mixture of antimony and potassium permanganate, and for milli second delay detonators is a mixture of red lead and silicon. These delay elements burns at a specified rate and the delay varies with the length of the sleeve containing delay element. The number of delay is marked on a disc fixed to the leading wires. The colour of the leading wire of half second delay detonators is one red and the other is yellow, in a case of milli second delay detonators, both the leads are coloured by red. By the delay detonators, cousumption of explosive is reduced as blasting is more efficient due to availability of free face, fragmentation of the rock is increased, time requirement for the blasting is saved, produce less ground vibrations.

Purpose of its use :—

These detonators are used in stone drifting, sinking pits, mechanised quarries, where simultaneous shot firing is in practice. Half second series are used in stone drifting operation, where the number of shot holes in a round is not more than eleven, whereas milli second series are used in shaft sinking, drifting and quarries, where number of shots in a round is more. It is observed that the milli second detonators produce less ground vibrations than half second delay detonators.

Precautions :—

(1) No delay detonators shall be used below-ground without the permission of D.G.M.S.

(2) Ordinary electric detonator and delay detonator should not be kept in the same case or container.

(3) The primer charge with delay detonator should be inserted first into the hole with the detonator base pointing towards the main charge of explosive.

(4) The interval between the first and the last shot of the round, calculated by references to the markings on the delay detonators should not exceed 0·1 second.

(5) The leading wires of delay detonators should be of sufficient length to make the connection without adding extra wires.

Q. 11. *State some of the reasons for restricting the use of delay detonators to stone drifts and sinking shafts.*

Ans. The most important reasons for such restrictions are :

(*a*) danger of firedamp and coal dust ignition,

(*b*) danger of fires,

(*c*) danger of misfired charges being sent out with the coal,

(*d*) danger of incendive sparks from the exploder used for delay action detonators.

(*e*) In case of *instantaneous shot firing*, we take three sets of safety measures to prevent ignition of fire damp and coaldust :

(1) We check the percentage of fire damp in the atmosphere and spray water or apply stone dust to eliminate the risk from coal dust,

(2) the explosive charge is given a suitable confinement by means of stemming and

(3) we use only permitted explosive.

In delay shot firing the first two conditions can not be satisfied with absolute certainty. Firedamp may be released by the earlier shots in the round, coal dust too will be produced and the successive charges of the round will be fired in a gassy and dusty atmosphere. On the other hand, some earlier shots in the round may expose others to unexpected dangers, such as ;

(i) stemming may be cut off,

(ii) the burden of the shot may be considerably reduced resulting in the exposed charge firing in direct contact with the atmosphere and

(iii) the cartridge may be projected with the broken material and detonate outside the shot hole.

(*b*) *The initiation of fires by burnning charges* are mo frequently reported where delay detonators are used i coal. The conditions need for an explosive to give ris to burning are :

(i) failure in transmission of detonation must occur ;

(ii) the charge must remain confined for a fraction of second so that it is maintained at a certain temperatur and sufficiently high pressure by the gaseous produc resulting from the detonated part of the charge. Th uncertainty of transmission of detonation is increase by delay shot firing.

(*c*) and (*d*)—These are inherent dangers with dela firing.

To *avoid the above dangers* which are involved in th use of delay detonators, their use is restricted, when fire damp is not normally present and chance of coa dust production do not exist and so this restriction i imposed.

Q. 12. *What are the essential requirments of an explode for mining use ?*

Ans. The chief requirements of an exploder for minin use are as follows—

(1) The exploder must be capable of firing the prescribe number of detonators of appropriate type, connected properly in a circuit.

(2) The possibility of igniting firedamp by electrical sparks from the exploder should be eliminated or be reduced to an acceptable limit.

(3) The exploder should be so constructed that its firing circuit is made and broken either automatically or by means of a push button switch.

(4) In the capacitor discharge type of exploder provision should be made for automatically discharging the capacitor at the completion of the operating sequence.

(5) The exploder can be operated only by a removable handle or plug.

Q. 13. *Outline the general construction of an exploder and mention what precautions should be taken to prevent the ignition of firedamp, during its use in the mine.*

Ans. There are two chief types of shot-firing apparatus, namely, (1) Magneto exploders, and (2) Battery exploders.

I am giving the outline of the general construction of the first type.

Magneto exploder—These consist essentially of a permanent steel magnet between the poles of which an armature revolves, being actuated through gearing by a rotary handle, or by a rack and pinion. The whole assembly is enclosed inside a casing, on which is provided two terminals, and also an aperture for the handle. These exploders may be either low tension or high tension.

In the low tension type, the armature consists of a small number of turns of thick wire whereas in high tension type : The armature consists of a large number of fine wires.

Precautions to prevent fire damp ignition :

(1) No apparatus shall be used which is defective ; and every apparatus shall, once at least in every three months, be cleaned and thoroughly overhauled.

(2) If any apparatus fails to fire all the shots in a properly connected circuit, the shot fire shall return the apparatus to the manager, undermanager or assistant manager and it shall not be used again unless it has been tested on the surface and found to be safe working order. The result of every overhaul, test or rapair shall be recorded.

(3) No such apparatus shall be tampered with or opened by any unauthorised person.

(4) When a low voltage and low power exploder is operated, spark may be produced if unwanted contact

occurs between two uninsulated parts of the circuit or
the normal circuit is broken, on the other hand a hig
voltage exploder is capable to produce sparks even whe
insulation of the airgap between the two conductor
which are not in contact, breaks down.

To prevent this type of pre-firing sparks, well-insulate
cables should be used and the joints between cables, lead
etc. should be properly made.

(5) There may be post-firing sparks, if the explode
output current is not ceased after a round of shots is fired
The 4 m. sec. cut-off is provided to minimise the chance
of such post-firing sparks.

BLASTING IN MINES

Q. 14. *Write short notes on : (a) Direct initiation
(b) Inverse initiation, (c) Blown out shots, (d) Miss
fired shots.*

Ans. (*a*) When charging a hole, if the primed car
tridge containing the detonator is inserted last of all with

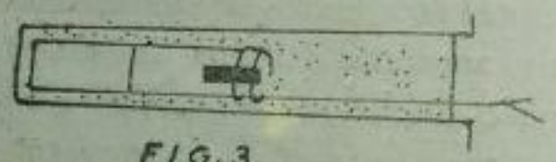


FIG. 3
DIRECT INITIATION

its business end pointing towards the main body of the
charge, it is known as *direct initiation.* Points in its
favour are—

(1) chance to cause ignition of fire damp is less.
(2) reduces the risk of blown-out shots and ensures
complete detonation.

It should be adopted for all normal shot firing except
delay firing.

(*b*) When the primed cartridge is inserted first, with
its business end pointing towards the front of the hole,
the procedure is known as *inverse initiation.* This method

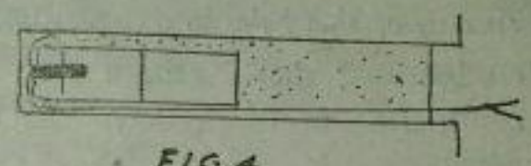


FIG. 4
INVERSE INITIATION.

must be adopted for multi-shot delay blasting to avoid
socket containing part of the charge unexploded.

In "*sumping*" or "*cut*" holes in sinking shafts and drifts
this method gives better rock pull.

(*c*) A *blown out shot* is one which has done no useful
work but has merely projected itself out of the mouth of
the shot-hole, carrying the stemming with it.

Causes of blown out shots are undercharging of shot holes,
unsatisfactory stemming, wrong direction of shot hole e.g.
in sumping shots in stone drifts the holes being perpendicular
instead of at some smaller angle

(*d*) A *miss-fired shot* is one in which the detonator
fails to explode or having exploded fails to ignite the charge.

The main *causes of complete failure* of the detonator are
defective shot-firing exploder, bad connection between
exploder and shot firing cable, defective shot firing cable,
bad connection between detonator and shot firing cable,
broken detonator leads, faulty detonator and the main causes
of incomplete detonation are weak strength of explosive,
inadequate stemming, improper charge in the hole.

Main precautions against miss-fire include :

(1) Use properly tested exploder, good shot-firing

cable, sufficiently powerful detonator and charge hole by explosive in sound condition.

(2) Make the connections carefully.

(3) Handle the detonators carefully to avoid broken leads.

Q. 15. *What do you understand by well-balanced shots? Describe the chief factors, which influence the location, direction and spacing of shot holes in a coal seam.*

Ans. Well balanced shot means a shot in which the charge is just sufficient to break down the coal without wasting any energy.

The chief factors which influence location, direction and spacing of shot holes in a coal seam are :—

(*a*) *Thickness of the seam*—in the thin seams, the holes must be drilled closer together because the burden or thickness of coal to be blasted is small, and consequently there is not much side spread from the shots.

For thicker seams double row of holes will be needed in order to get well balanced shots. The bottom row should not be too close to the floor. It is usual to stagger the holes in top and bottom row, so that they are directly above one another.

(*b*) *Position of cut in the seam*—undercutting of face is the general practice, but sometimes they are cut at some intermediate point in the seam or the seam may be overcut leaving a coal roof.

The general rule is, the back of the hole should be a distance from the cut equal to about two thirds or three fourths of the depth of the hole, but the tops or bottoms are likely to be thiner in relation to the depth of the hole or the cut and there will be a tendency for the shots to blow through at the back of the hole, without breaking the front coal.

These holes should be spaced closer together and should be charged lighter than the holes in other part of the cut.

(*c*) *Presence of hard band*—if there is any hard band in the seam, the charge of the explosive should be as close to

hard band as possible. The shot holes should be either in hard band or just above it. In case of weak roof, this should be protected by placing the shot holes just below the band.

(*d*) *Nature of parting at the roof*—where the parting between the seam and the roof is sticky, the hole should be so drilled that the charge of explosive will be almost in touch with the parting but care should be taken not to drill through the roof.

(*e*) *Presence and direction of cleats*—If there is well defined cleats in the seam, best direction of shot holes will be right angle to the cleat direction.

Q. 16. *What is "Cushion blasting"? What advantages are claimed for this method of shot firing?*

Ans. Cushion blasting is a technique which is used only in certain circumstances to get more round coal. An air gap is left between the outer end of the cartridge and the stemming in this method instead of inserting the stemming right up to the last cartridge.

The length of the stemming should be approximately equal to that of the charge and stemmed upto to the end of the hole as tight as possible to prevent blown out shot.

The effect of the air gap is to spread over the explosive energy over greater area and so lower the intensity of the blow. Ammonium nitrate explosive containing no nitro-glycesine should not be used as that explosive become too insensitive in this method.

Advantages—

(1) Where the burden of coal or stone to be blasted is thin in relation to the length of the hole or depth of the cut, for example, in seams where the coal is cut in a dirt band, perhaps at some intermediate point in the seam, leaving thin sections or layers of coal to be blasted, or where coal seams are over-cut, thin layers of coal

being left on the roof, normally, when shots are fired in the above conditions, there is very little spread and there is a tendency for them to blow through at the back of the

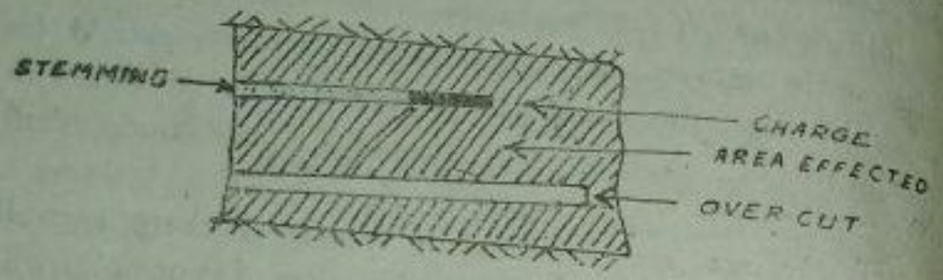


FIG. 5
NO CUSHIONING 'FRONT' LEFTON

hole leaving *"fronts"* of coal still in position. By spacing these holes closer together, using lighter charges and adopting the cushion blasting method, better results will be achieved.

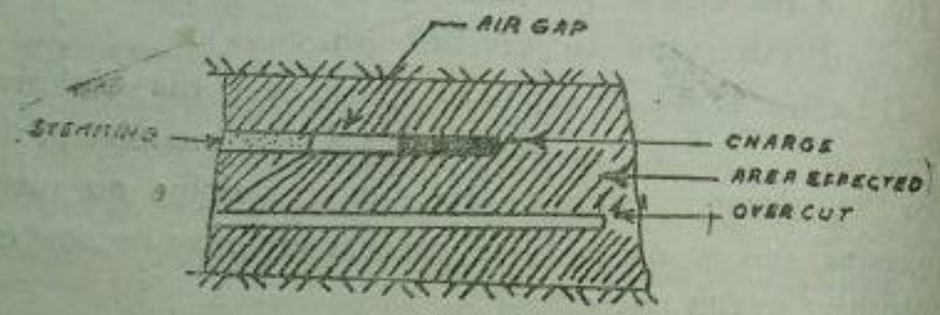


FIG. 6
CUSHIONING NO 'FRONT' LEFT ON.

(2) Employed in a similar manner for blasting thin layers of roof ripping or floor dinting when heightening road ways.

(3) More round coal is produced.

Q 17. *What is pulsed infusion shot firing. Discuss advantages and disadvantages of it over conventional shot-firing.*

Ans. Pulsed infusion shot firing is a combined blasting and water infusion technique. The technique essentially consist of the following operations—

(1) Infusion the coal with water under pressure.
(2) Charging the shot holes with special water-resisting type explosive.
(3) Re-insertion of the infusion tube in the mouth of the shot holes.
(4) Firing the charges whilst the water is under active pressure.

No stemming is needed in this method.

Advatages

(1) High order of safety against ignition of gas as any break in the coal remain water filled.

(2) High degree of dust and fume suppression.

(3) The explosive energy is more effectively utilised because the high pressure impulse produced by the shot is transmitted through out the water distribute in the cleavage planes and breaks, resulting in a greater spreading action for a given weight of charge.

(4) More round coal is produced.

(5) Dealing with the miss-fire is easy, remove the infusion tube and insert a new primer cartridge in contact with the miss-fired charge.

(6) The system opens up the possibility of enabling coal to be fired safely off the solid.

(7) No stemming is needed.

Disadvantages

(1) The seams containing fractures and breaks can not be infused effectively hence the technique is not applicable to every seam.

(2) The water may have bad effect on roof or floor and strata control may be difficult.

(3) When firing there may be a severe impact on the infusion tube which may project the tube from the hole. This is not only hazardous in itself but may produce frictional spark.

(4) More equipments are needed and special drilling equipment for long hole is needed.

(5) It is open to misuse in case of non-availability of water.

Q. 18. *Enumerate the equipments required for pulsed infusion shot firing and describe the technique.*

Ans. *Equipments required*—

(1) Supply of water at high pressure.

(2) Lengths of high pressure armoured hose. Spring-loaded automatic valves may be spaced at intervals of 11 m to prevent any back-pressure, produced by firing the shot which may damage the water main or the pump.

(3) Infusion tubes in which the pressure of the water is utilised automatically to expand the rubber seal and so seal the hole.

(4) Pressure gauge, flow meter, and stop valve mounted together in the pressure hose line in a safe position.

(5) *Drilling equipment*—special drilling equipment is needed to bore long holes.

(6) *Special water*-resisting permitted explosive—one of such explosive is Hydrobel.

(7) *Submarine electric detonator*—Hydrostar.

(8) Cordtex detonating fuse for long hole blasting.

Shotfiring technique—There are two methods of application :

(1) Long hole method, applicable to long wall faces and the sides of rooms in pillar and stall work ;

(2) Short or flank hole method, applicable to stable holes faces of rooms or short walls and also long wall faces.

In either case the coal is blasted from the solid.

Long hole method—

As shown in the sketch, one hole is drilled parallel to the face from one end of the face to the other keeping about 1-m burden. A stable hole is needed at each end of the face to enable the hole to be drilled or alternatively in retreating face, the headings already driven may serve the purpose. Ensure a high degree of accuracy of drilling in

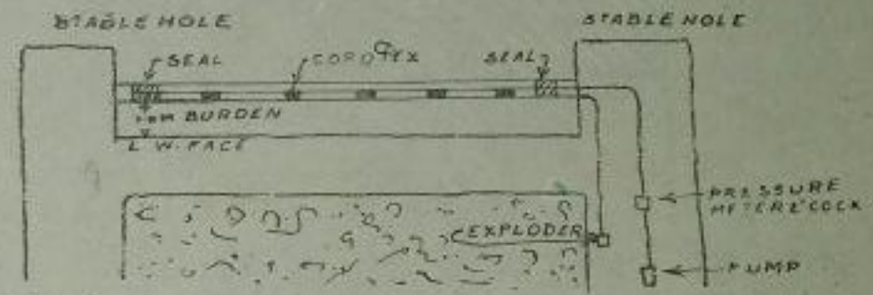


FIG. 7
LONG HOLE PULSED INFUSION BLASTING

both the horizontal and vertical planes. Special machines, with accurate sighting arrangments, are being designed for the same purpose. The coal is pre-infused before charging the hole and for that one end of the hole is closed with a screw-type sealing plug fitted with an air release cock.

A standard hydraulically sealed infusion tube is inserted into the other end and the coal is infused, after that the infusion tube and seal, are withdrawn. The charge is prepared on the surface by threading the special explosive cartridge Hydrobel on detonating fuse Cordtex and the ends of the Cordtex are sealed by empty detonator tubes. The charges are transported undergound in a special carriage. The hole is charged by the pre-prepared charge with the help

of a cord which is placed in the hole with the help of drill rod. The infusion tube is then re-inserted in the firing end. The hole is re-infused end when the water is seen issuing from the other end, the sealing plugs are inserted to close and infusion is continued. Finally after carrying out the statutory inspection, the shot is fired.

Flank-hole method—

The holes are drilled at an angle of 30° to 60° to the face line the burden being of the order of 1·5 m. The

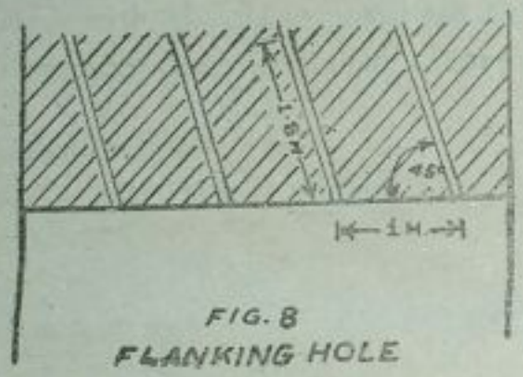


FIG. 8
FLANKING HOLE

initial infusion is then carried out by inserting the infusion tube as in long hole method. The holes are then charged in the normal manner and the hole is re-infused and after doing the statutory inspection the shot is fired whilst the infusion pressure is still maintained.

Q. 19. *What steps would you take to ensure complete detonation, of a charge in a shot-hole? What disadvantages are attached to incomplete detonation?*

Ans. Taking the explosive supplied is in sound condition and that a normal detonator is used, the necessary *precautions* to be taken are—

(1) Clean the hole properly to ensure that the cartridges, when pressed home, are touching one another.
(2) See that the diameter of the cartridge is just slightly less than the diameter of the hole.

(3) Use as few cartridges as possible to make up the required weight of charge.
(4) Avoid using ammonium nitrate explosives in wet shot holes, especially those of the non-nitroglycerine type.
(5) Stem the hole throughly with an adequate amount of stemming.

The *disadvantages* of incomplete detonation—

(1) Some of the power of the explosive is wasted.
(2) The danger of igniting firedamp is increased.
(3) The production of carbon monoxide and nitrous fumes is increased.

Q. 20. *Describe the principal firing patterns for shot firing with delayed action detonators in stone drifts. Discuss the relative merits of each pattern.*

Ans. When blasting in stone drifts there is no free face until one is created by blasting.

It is therefore necessary to arrange the holes in such a way, and fire them in such a sequence, that each group of hole in succession provides a free face for the next following group.

Various patterns of holes have been used, including (a) drag cut, (b) fan cut, (c) pyramid cut, (d) wedge cut and (e) burn cut.

The *drag cut*, fan cut and pyramid cut have given way in present time to the wedge cut and the burn cut because the drag cut is mostly applicable in soft well laminated strata and does not lend itself to great depths of advance.

The *fan cut* is relatively difficult to drill and becomes progressively more difficult as greater depths of advance are aimed at.

The pyramid cut is for extremely hard rocks which are generally not found in coal mines.

In *wedge cut*, the holes are drilled in the form of a triangular wedge usually horizontal but some times vertical.

Two or more pairs of cut holes marked O, (the number depending on the height of the drift, directed towards each other and fired simultaneously so breaking out a wed-shaped

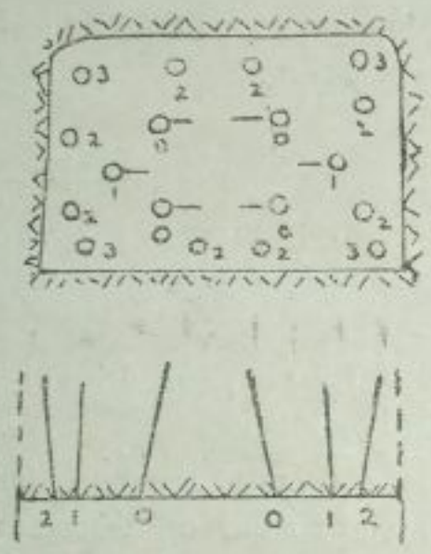


FIG. 9
WEDGE CUT

prism at the centre of the drift. These are followed by the easers marked 1, the trimmers marked 2 and finally the corner shots 3. Increased fragmentation can be achieved in the cut area by the use of stab holes drilled in the centre of the wedge.

In *burn cut*, shot holes are drilled in a cluster at right-angles to the face at close and uniform centres and

parallel throughout their length. One or more of the holes is left uncharged.

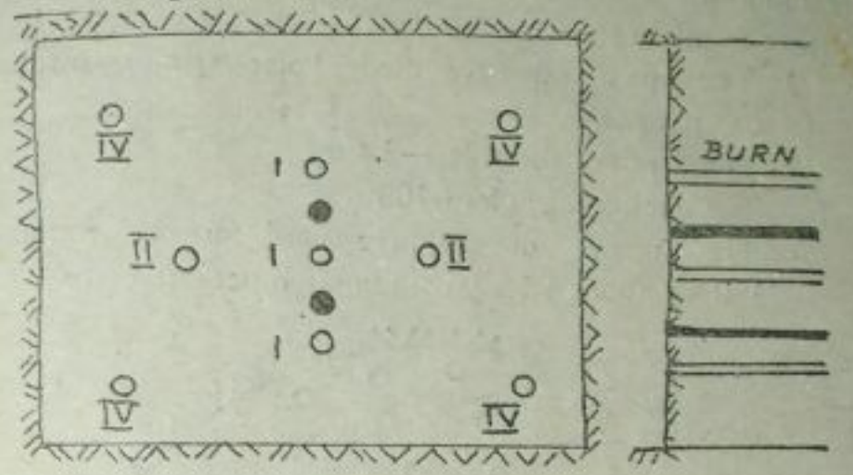


FIG. 10
SHORT DELAY DETONATOR NUMBERS SHOWN IN ROMAN NUMERALS.

BURN CUT

The *advantages* claimed for the burn cut are :

(1) increased depth of pull ;
(2) it is easily and quickly drilled and the width of the drift is not restrictive to drilling ;
(3) causes minimum damage to roof-supports during blasting.

The burn cut is very effective in hard brittle homogeneous strata.

Q. 21. *Describe and show by a sketch, the placing of the shot holes in a sinking shaft, 7-8 m. diameter excavated cross section.*

Give in details (a) type of explosive used, (b) depth of holes, (c) number of holes, (d) amount of explosive used per round and (e) method of firing.

Ans. The adjoining sketch shows the placement of holes. Eleven holes at the centre are drilled to form a pyramid cut and the rest holes are arranged in a number

of concentric rings. The complete round of shots is fired by means of milli-second delay detonators in one round. Further details are :—

(*a*) The type of explosive used—Polar Ajax or unisax-G or viking-G.
(*b*) The depth of the holes—2.4 m.
(*c*) The number of holes—108
(*d*) The amount of explosive used for one round—180 kg. about 1·5 kg. consumption per cu. metre.

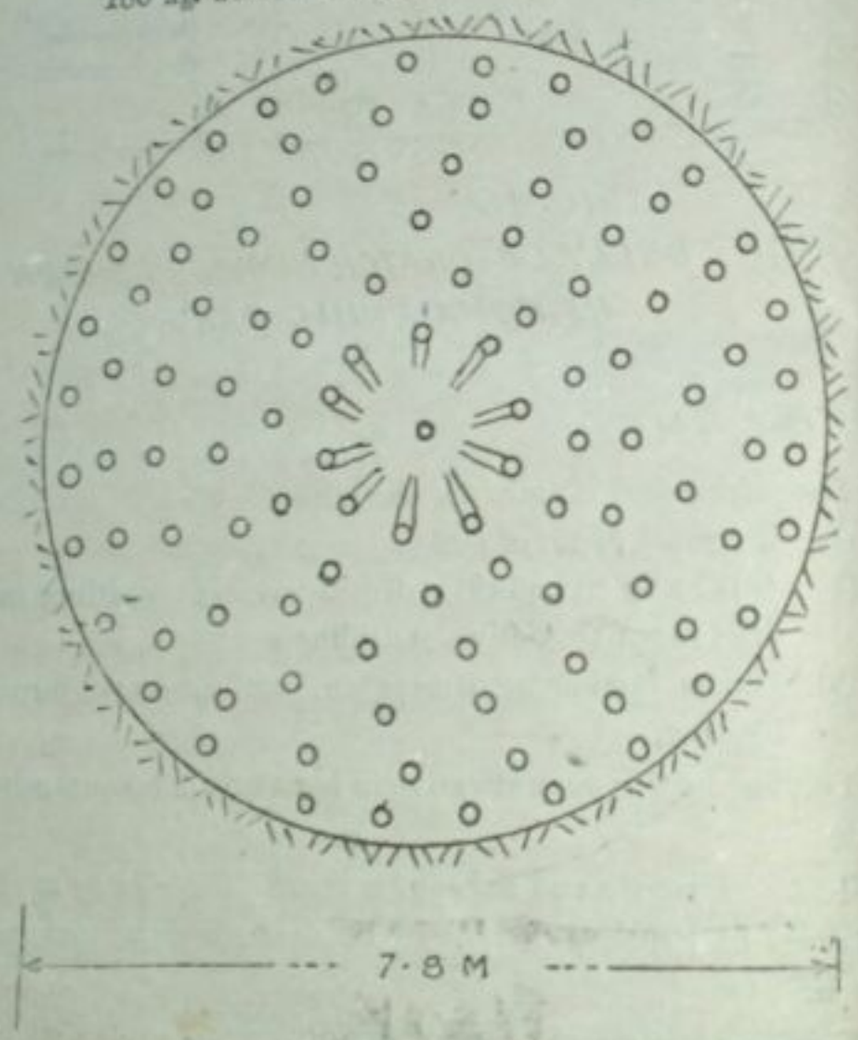


FIG. 11

(*e*) *The method of firing*—Firing is done from 550 volts A.C. mains from the surface with the statutory permission, from the D.G.M.S. The holes are connected in parallel by Copper/Aluminium bus bar rings laid on the shaft

bottom and then connected to the surface by a twin core cable in the shaft. The advantages of firing in parallel from main is to put down the misfire and subsequent

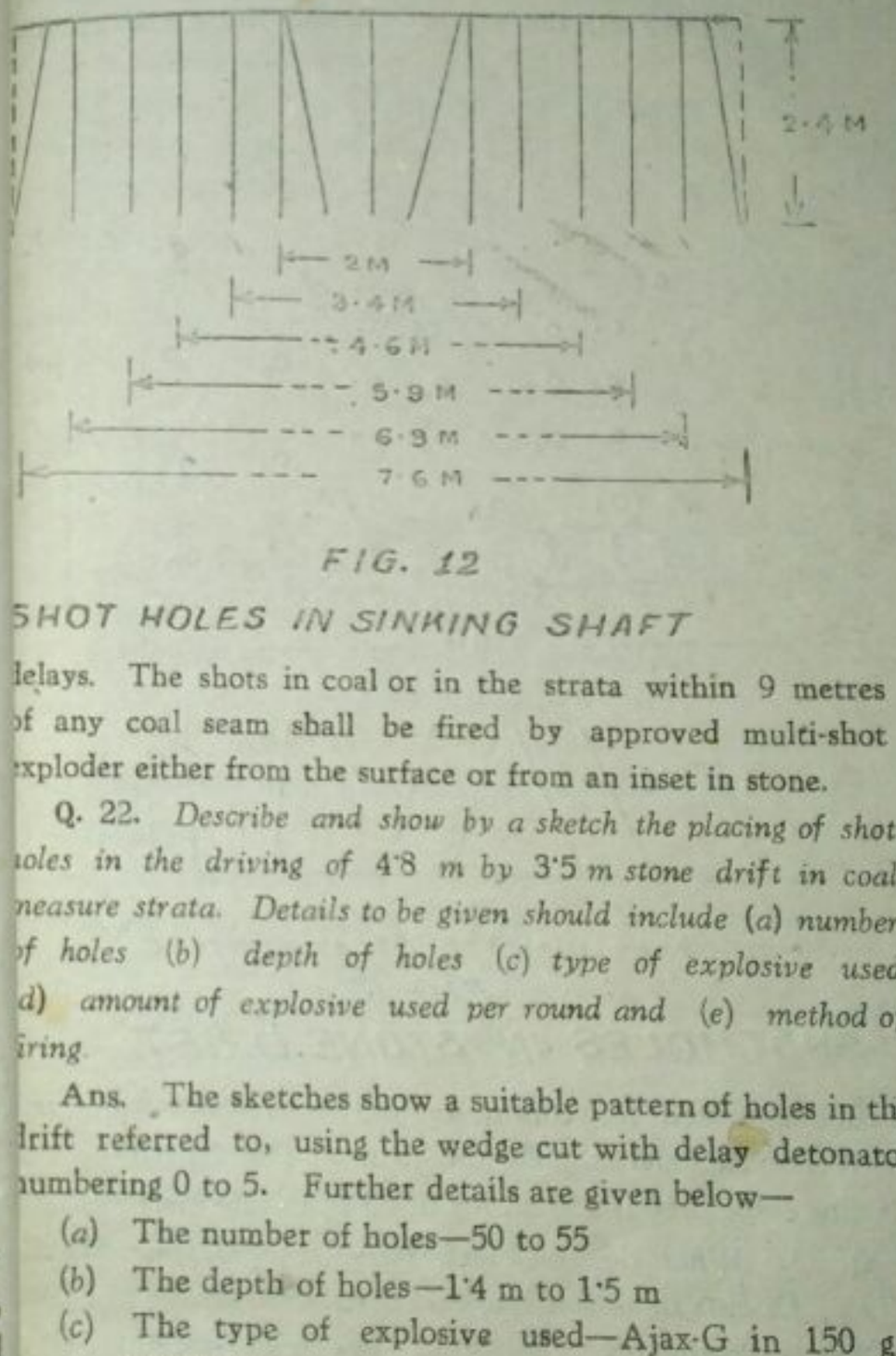


FIG. 12

SHOT HOLES IN SINKING SHAFT

delays. The shots in coal or in the strata within 9 metres of any coal seam shall be fired by approved multi-shot exploder either from the surface or from an inset in stone.

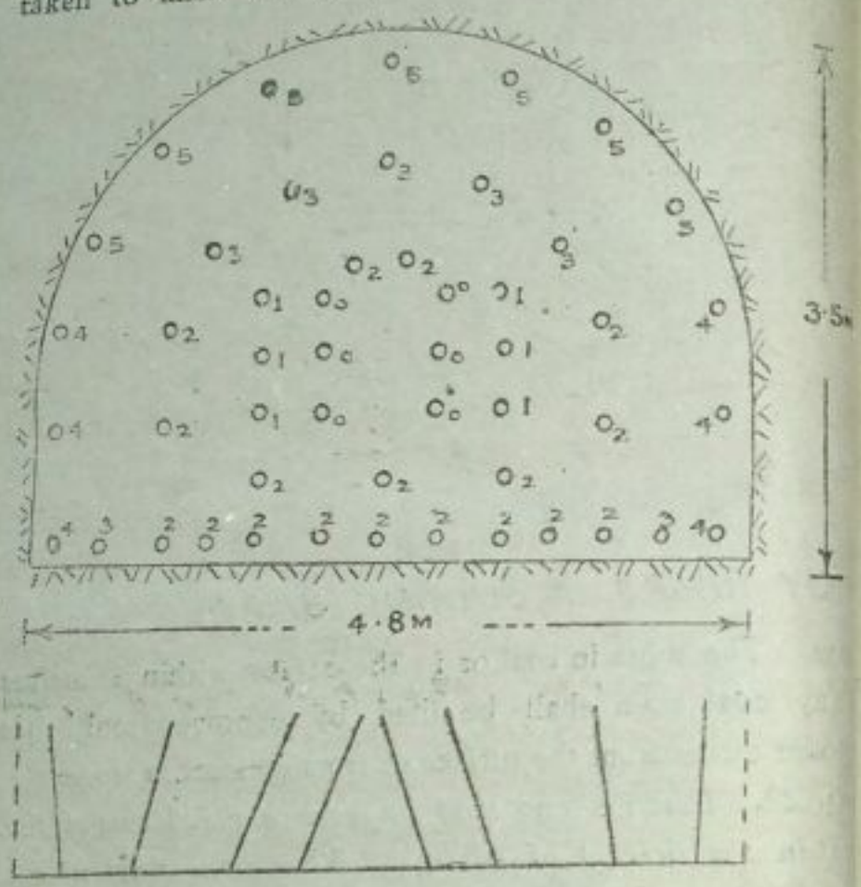
Q. 22. *Describe and show by a sketch the placing of shot holes in the driving of 4·8 m by 3·5 m stone drift in coal measure strata. Details to be given should include (a) number of holes (b) depth of holes (c) type of explosive used (d) amount of explosive used per round and (e) method of firing.*

Ans. The sketches show a suitable pattern of holes in the drift referred to, using the wedge cut with delay detonator numbering 0 to 5. Further details are given below—

(*a*) The number of holes—50 to 55
(*b*) The depth of holes—1·4 m to 1·5 m
(*c*) The type of explosive used—Ajax-G in 150 gm. cartriges.

(*d*) Amount of explosive used per round—25 kg. t
30 kg.

(*e*) *The method of firing*—All the shots would be connec
ted in series by two single-core cables. Care should b
taken to make all the joints. Before firing the circui



NUMERALS INDICATE DELAY NUMBERS

FIG. 13

SHOT HOLES IN STONE DRIFT

should be tested for continuity and resistance. Approv
multi-shot exploder is used for firing. The length of t
blasting cable used is 150 m. for firing from safe distance.

Q. 23. *What do you understand by blasting-off t
solid ? Discuss its advantages and disadvantages.*

Ans. Blasting-off the solid or solid blasting is
technique of winning coal without providing a second f

face i. e. without doing any machine cut but by using ultra-safe explosive and non-incendive milli-second delay detonators.

Advantages—

(1) *Improved productivity* due to reduced cycle time, tracks are possible to be laid upto the face, reduced down-time of cutting machines.

(2) *Flexibility of operations*—applicable even in conditions where the use of coal cutter is difficult such as steep inclination, irregular floor, working above caved areas etc.

(3) *Saving in capital equipment* : Costly coal cutting machines, and the electrical equipments needed for the same machine are dispensed with.

(4) *Saving in lead payment* as tracks can be laid right upto the face.

Disadvantages—

(1) Additional *magazine capacity* is needed as the explosive and detonator requirement is 2 to 3 times the requirement in conventional blasting.

(2) Additional *expenditure for transport* of this extra explosive from the surface to the faces.

(3) The additional *risk of accidents* involved during the transport, handling and use of such increased quantities of explosive.

Q. 24. *What are the conditions generally imposed by the D. G. M. S. to introduce solid blasting in different mines ?*

Ans. *Conditions generally impose* :

(1) During the initial two weeks period, the blasting shall be done under the direct supervision of an officer of the Technical Service of an explosive company, when sufficient number of overman and mining sirdar etc. shall be trained to undertake the work.

(2) No explosive other than the permitted explosive for solid blasting and "Anticendive" milli-second delay detonators shall be used.

(3) *The pattern of shot holes*, the amount of charge in each hole etc. shall be laid down by the manager in consultation with the officer of the explosive company.

(4) *In devising this pattern*—

(a) The estimated period of delay between the firing and last shot of the round calculated by reference to the marking on the detonators shall not exceed 0·15 second (150 milliseconds).

(b) The estimated period of delay between any two adjacent shots shall not exceed 0·06 second (60 milliseconds.)

(c) The minimum distance between two adjacent shot holes shall not be less than 0·6 metres any where along their lengths.

(5) In Category II seams at least 284 cubic metres of air per minute shall be conducted within 3 metres of every face where solid blasting is being done.

(6) Tests for inflammable gas shall be made at and within a radius of 20 metres of the place of firing with an approved type methanometer bya person holding a manager's/overman's certificate and no shot shall be fired if 0·5% or more inflammable gas is found at any place in the said zone.

(7) The shot firing operations shall be carried out only by a person holding either a manager's or a overman's certificate or a Sirdar's certificate along with a degree in mining Engineering from a recognised institution.

(8) *The shot firer* :—

(*a*) shall not fire more than 25 shots in one round,

(*b*) shall strictly adhere to the pattern of shot holes and charge per hole etc. laid down by the manager, and

(c) shall carry out all statutory inspections and precautions for inflammable gas etc.

(9) The roof, floor and sides of all workings within 90 metres of the place of firing shall be thoroughly drenched with water.

10. (a) The exploder shall be of an approved type and maintained in perfect working condition.

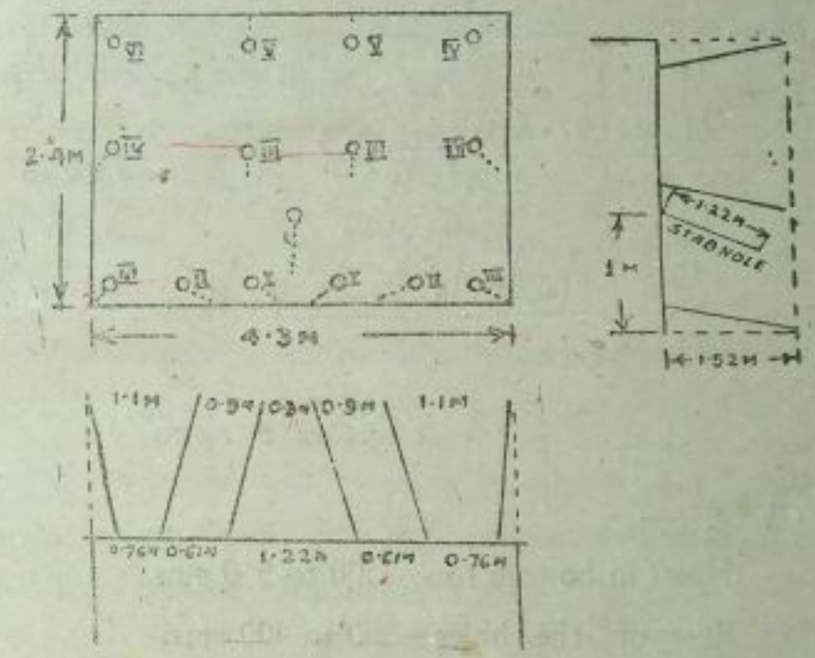
(b) The shot firer shall be warned to take due precautions for the high voltage output of the exploder while handling the same.

(c) The cable for shot firing shall be of an approved type and adequate for the maximum voltage output of the exploder.

(d) All connections between the shot firing cable and the detonator leads as well as between the consecutive leading wires shall be done properly.

Q 25. *Describe in short with the help of sketches solid blasting operation in a development face and in a longwall face.*

Ans. Explosive energy is better utilised when two free faces are available. In solid blasting, the second free



THE ROMAN NUMERALS INDICATE DELAY SEQUENCE

FIG. 14

DEVELOPMENT FACE

face is created by firing shots to break out a cavity known as the cut. The cut is then further enlarged to the desired cross-section of the face by means of firing more

shots in a pre-determined sequence. The initial cut is created by using either a wedge cut, fan cut, pyramid cut or a combination thereof. The wedge cut is mainly used in headings. The fan cut is the most suitable pattern for blasting in longwall face; it is also preferred in headings where there is cleavage planes in coal, and where the coal near the floor is tough.

Solid blasting in development face—

Size of the face—4·3 m by 2·4 m,

Explosive used—SOLIGEX

Detonators used—CARRICK short delay detonator

No. of holes —15

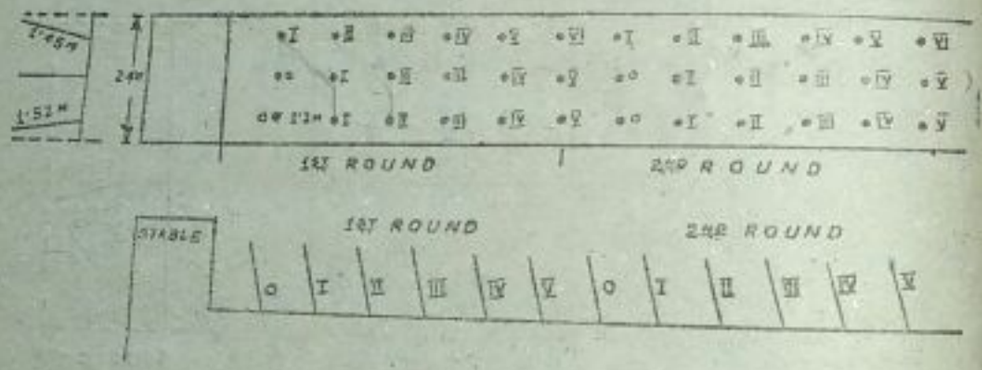


FIG. 15
LONGWALL FACE

Charge :—

Holes in bottom row—500 to 550 gms.

Rest of the holes—350 to 400 gms.

Total charge —6 to 7 kg.

Blasting ratio —2·6 to 2·8 tonne/kg.

Yield/detonator —1·1 to 12 tonne

Pull —1·38 m to 1·52.

Solid blasting in longwall face :

In each round 18 shots are blasted. The delay sequence is indicated by Roman numerals in the sketch. Blasting ratio and yield/detonator is better than in the case of development face.

Q. 26. *What exemption from the Coal Mines Regulations, 1957 may be required before introducing solid blasting in a coal seam ?*

Ans. *For exemption :*

(*a*) to blast off the solid, from the Regulation 173 (a) (i) i.e., No shot shall be fired in coal unless the coal has been undercut, over cut or side cut ;

(*b*) to use delay detonators, from the Regulation 175 (5) i.e. No delay-action detonator shall be used, except with the previous permission in writing of the Chief Inspector ;

(*c*) to fire rounds of more than 10 shots in coal, from the Regulation 168 (15) i. e. Except in a stone drift or a sinking shaft, not more than 10 shots shall be fired in any one round. When more than six shots are to be fired in one round, they shall be fired electrically.

EXPLOSIVES AND BLASTING TECHNIQUE IN OPENCAST

Q. 27. *Write short notes on : (a) deck charging (b) secondary blasting.*

Ans. (*a*) When the *overburden of opencast* is composed of alternate hard and soft bands, the explosive charge is located opposite the hard bands instead of placing the major portion of the charge at the base of the hole. The intervening spaces between charges in a hole are filled

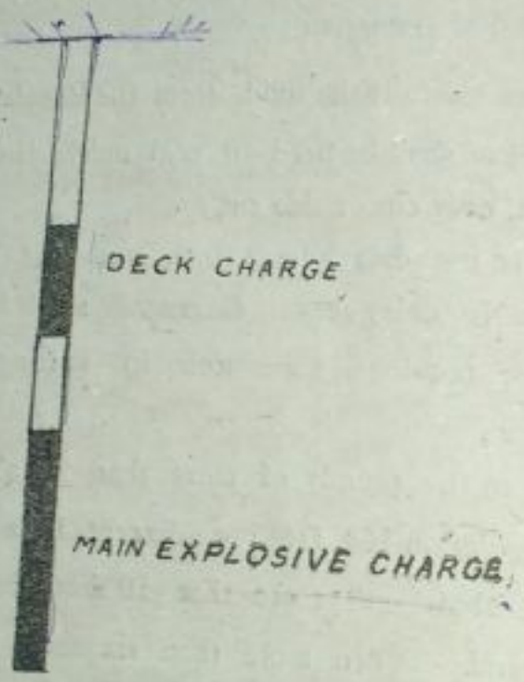


FIG 16
DECK CHARGING

with stemming (consisting in most cases of drill-hole gumming) and the top of the hole is stemmed up to the Collar. This method of charging is known as *deck charging*.

(*b*) The *secondary blasting* is done break over-size boulder, produced during primary blast, to size, suitable

for handling. There are two basic methods of secondary blasting,—*Pop shooting* and *Plaster shooting*.

For Pop shooting a hole is normally drilled just beyond the centre of the boulder to be broken. With some kinds of rock shot holes 30 cm deep are sufficient to break every large boulder.

The charge varies with the size of the boulder. The shots are fired either by safety fuse and plain detonators, or by electric detonators. It is necessary to withdraw mechanical loading equipment to a safe distance, since there is considerable scatter of rock when firing pop shoots.

On the other hand, plaster shooting provides a ready means of breaking even large boulders in circumstance where drilling is difficult or expensive. A charge of Plaster Gelatine primed with a detonator and safety fuse, or an electric detonator is laid on the surface of the boulder, it is then covered with a shovelful of plastic clay, which is pressed into position by hand.

In plaster shooting, the charges used are about four times those required for pop shooting but plaster shooting do not require drilling, a group of shots can be prepared far more quickly than the same number of pop shots. fragmented material is not scattered over a wide area.

Q. 28. *Give a brief description of explosives used in opencast mines.*

Ans. *O. C. G.* (*Opencast Gelignite*) : It is nitro-glycerine based, high density (1·5) explosive. Velocity of detonation is 2500 m/sec. for 75 mm to 100 mm diameter cartridges and 4000 m/sec for 125 mm and above diameter cartridges. It is a cap-sensitive explosive and is detonated by detonating fuse or detonator. It is suitable in deep, highly watery holes and for hard formation.

GNI (*Gomia Nitrate*) : Premixed ammonium nitrate and fuel oil explosive in cartridge. For optimum detonation it requires a primar of O. C. G. or Primax. It is hygroscopic in nature and is a low density explosive.

The velocity of denotation is 3000 m/sec. It can be used in wet or moderately watery holes and for any depth.

Gomia Gelignite : 50%—40% :

Low percentage nitro-glycerine based explosive. It is suitable for coal, moderately hard shale in dry and moderately watery holes.

Large diameter Viking G :

It is a nitro-glycerine based powder explosive suitable for coal in dry holes.

LOX (Liquid Oxygen) :

Liquid oxygen soaked in combustible absorbent like wood pulp, carbon black, metal powder etc. in paper or cloth bag. The cartridge is prepared immediately before use at the spot of firing. Two types of cartridges are available,—ordinary for overburden blasting and Coal Cartridges (c.c. type), for coal blasting more cooling agents are mixed, which prevent firing in coal.

LOX is low density explosive when soaking percentage is below 60% and normally that is suitable for holes upto 45ft. depth and is used in shovel mines. Heavier type, high density Lox, suitable for highly watery holes above 45ft, depth is now available. When fully soaked it is capsensitive, detonated by detonating fuse or detonator. To prevent boulder formation and efficient toe breaking in watery holes and to prevent flying of stones the cartridges are covered in polythene bags and gunny bags with stemming material are used to keep it down.

AN/FO (*Ammonium nitrate and fuel oil explosive*) site mixed :—

2% to 10% by weight ammonium nitrate and fuel oil when suitably mixed it attains the property of high explosive. It is a low density explosive and is detonated by OCG as booster charge. The velocity of detonation is very high. AN/FO is hygroscopic in nature. It can be used in wet holes when it is packed in polythene bag. It is suitable

for any depth. For use in coal it is packed in double polythene bags.

Slurry explosives :—

These are the latest development of high density, high strength, water compatible ammonium-nitrate mixtures. These are in slurry form and fill the holes completely, giving rise to a greater packing density than achievable with conventional explosives, particularly in dry holes. The explosive power is also better utilised as the charge and the walls of the hole are intimately coupled.

Q. 29. *Describe the main factors which influence the burden, bench height, depth of hole, spacing between holes in opencast mines.*

Ans. *Burden* in a opencast mine is the perpendicular distance from the hole to the nearest free face in the direction in which displacement is most likely to occur. Its value is dependent on—

(1) the rock characteristics.
(2) the nature of explosive.
(3) the diameter of the hole and explosive.

In the case of free-flowing AN/FO or slurry explosives, which more or less fill the hole completely the diameter of explosive is taken as equal to the diameter of the the shot hole.

In other cases the difference between the diameter of the shot-hole and the diameter of the explosive should not exceed 25 mm.

Bench height : The height of a bench is fixed by the optimum operating limits of the drilling and loading equipments and the statutory direction.

Depth of hole : The depth of hole depends on the type of drilling equipment and on the height of the bench. As a rule, the depth of the drill hole should never be less than the burden. In practice, holes are drilled to a depth varying from 1·5 to 4 times the burden.

Spacing between holes—The spacing between holes depends on—

(1) the nature of the rock,

(2) degree of fragmentation desired, and

(3) the method of firing.

Where shot holes are fired simultaneously or at very short interval, the spacing should either be equal to, or less than 1·5 times burden. In very hard and tough ground the spacing may be less than the burden.

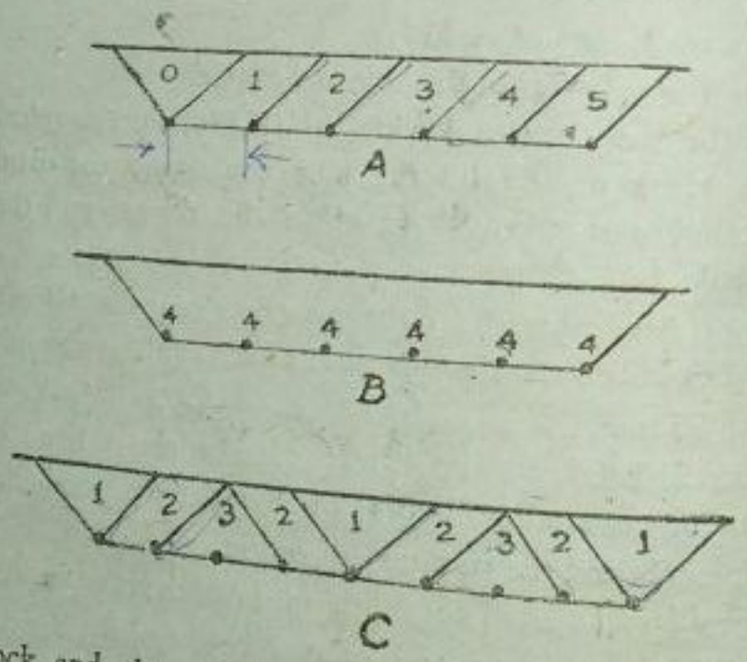
Q. 30. *Describe the firing patterns for shot firing with delayed action detonators in open-cast mines. Discuss their relative merits.*

Ans. Firing patterns in opencast may be classified into two main groups,—

(i) single-row firing and

(ii) multi-row firing.

In *single row firing*, the choice between firing the holes simultaneously or in a sequence depends on the nature of



the rock and the degree of fragmentation and throw desired. Delay firing of the series of holes in a row is done to obtain better fragmentation. The other *advantages*

of delay firing are the reduction in ground vibration, less back-break or over-break, and better control of the rock

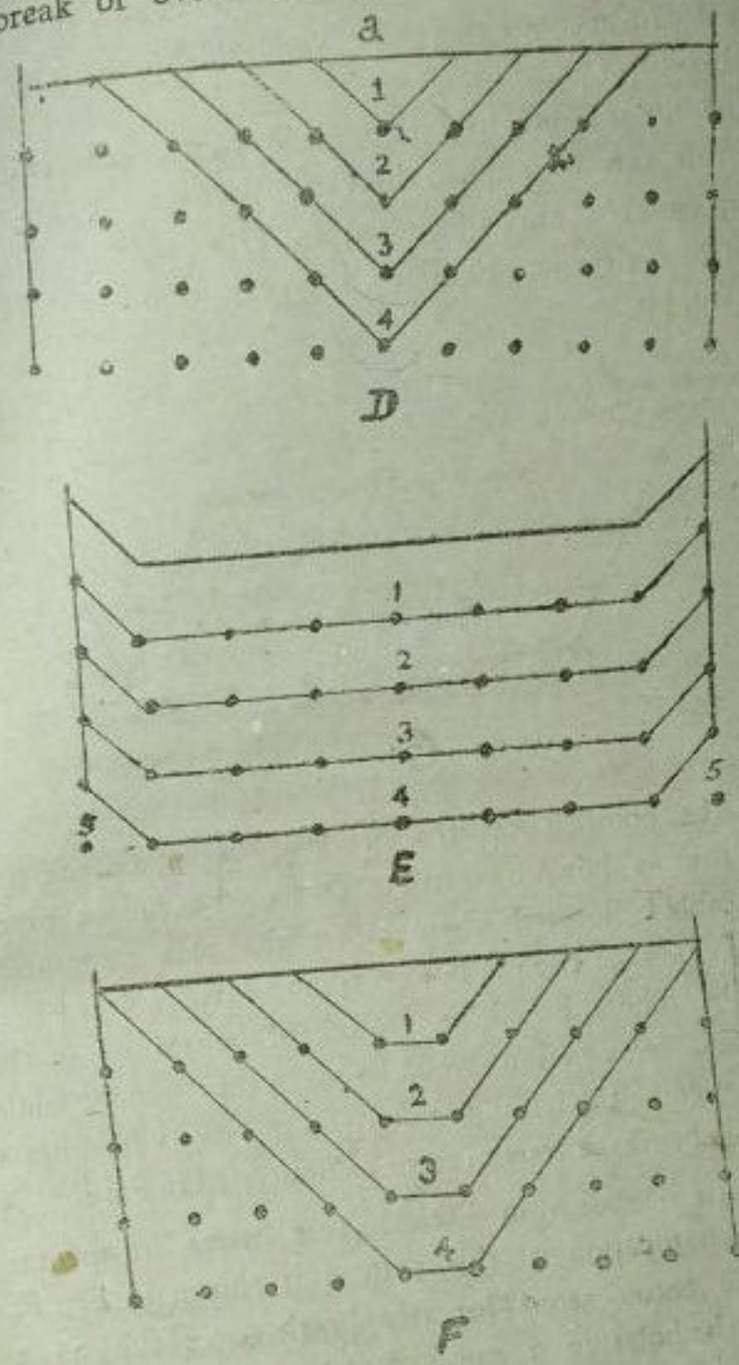
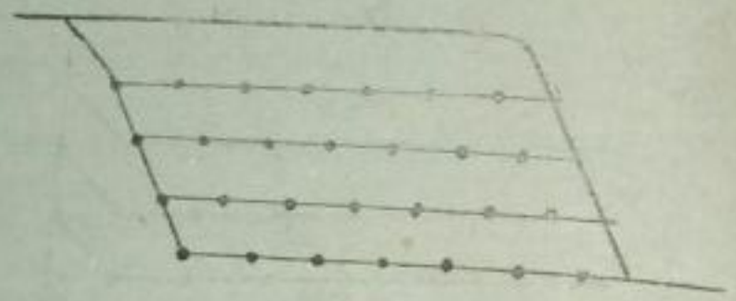


FIG. 17

pile. The delay interval is obtained by using short delay detonators, or detonating relays in conjunction with

detonating fuse. Two basic types of short delay blasting patterns for one row are illustrated in Figs. A & B, for improved fragmentation, the type shown in Fig. C is preferable.

In multi-row firing, the two basic short delay firing for single row can be applied in various ways. A few of the ignition patterns are illustrated in Figs. D, E, F, G. In initiating multi-row rounds of holes, two factors are important, viz,



G

(*a*) the point where the breakage begins on the first row as shown by *a* in Fig. D should as far as practi cable be located where either the rock structure is weakest or the the burden is most favourable, and

(*b*) the inherent ignition scatter of detonators of the same delay period should be taken into account while designing the ignition pattern so that every hole has a free breakage zone in front as illustrated in Fig E.

The pattern shown in Fig. D gives better fragmentation. A modification of this pattern is shown in Fig. F, which gives better scope for free breakage of the apex holes. All the holes in a row except the edge holes can be ignited with one and the same delay where by any hole that happens to be ignited first will have perfectly free breakage whichever it may be. In the case of benches with unlimited width, ignition pattern can simpler and

more reliable. Even when one interval per row is employed. It is possible to avoid the construction at the end holes by making the blasting finish diagonally to the face as shown in Fig. G

Q 31. *What do you suggest to eliminate the boulder and toes problem in the opencast mines.*

Ans. Boulder and toes problems can be eliminated by restoring to improved techniques as below—

(1) Select suitable drilling pattern, drill holes with an angle of inclination varying from 10°—40° to the vertical.

(2) Charge the shot holes by right amount of explosive.

(3) Select explosive of proper type for various formations.

(4) In strata composed of alternate hard and soft bands, charge the holes in 'decks'.

(5) Fire the holes in tight system.

(6) De water the holes before charging.

(7) Use suitable booster charge.

(8) Use short delay detonators and fire the holes in sequence.

Q 32. *What are the various ways to reduce the vibrations due to blasting in opencast mine on the neighbouring structures.*

Ans. The ways to reduce the vibrations are—

(*a*) Fire the holes in a sequence using suitable number of millisecond delay detonators.

(*b*) Introduce a discontinuity in the propagation medium. This can be done by pre-splitting i. e., by making a fissure in the ground in between the structures and the opencast mine. Any vibration due to blasting in

the opencast mine will not be able to propagate through split, but care must be taken so that the vibration of pre-splitting blasting itself does not cause damage to the structures.

(c) Dc the blasting efficiently by putting holes in proper burden and spacing and charging the holes properly. When the blasting is efficient, the most of the energy of the explosives will be utilised to break the rock and vibration will be less.

When the burded is too large, vibration will be severe, on the other hand when burden is too small there will be air blast.

(d) Use low-density explosive. High-density, high-strength explosives produce more severe vibration. ANFO explosive is more useful in reducing vibration.

(e) The quantity of charge with zero-delay should be kept to the minimum, in delay-firing.

(f) Drill the holes with the angle of inclination varying from 10°—40° to the vertical.

Q. 33. *What precautions shall be taken where explosives are transported in bulk for deep hole blasting.*

Ans. *Precautions*—

(1) Transport of explosives from the magazine to the priming station or the site of blasting shall not be done except in the original wooden or card board packing cases. The quantity of explosive transported shall not exceed the actual quantity required for use in one round of shots.

The explosive shall be transported to the site of blasting not more than 90 minutes before charging the holes.

(2) No mechanically propelled vehicle shall be used for explosive transport unless that is approved by the Chief Inspector. Every vehicle used for the transport of explosives shall be marked, on both sides and ends with the word "EXPLOSIVES" and shall be provided with at least two fire extinguishers (one of carbon tetrachloride

type for petroleum fire and the other of carbon dioxide type for electrical fire). The vehicle used for explosive transport shall not be overloaded.

(3) Jeep or land rover may be used for transport of detonators from magazine to priming stations subject to the following *conditions*—

(a) not more than 200 detonators are transported at a time ;

(b) the detonators are packed in wooden box ;

(c) the wooden detonator box is placed inside a metal case approved by the Chief Inspector ;

(d) the metal case shall be suitably bolted to the floor of the vehicle ;

(e) no person shall ride on the rear portion of the vehicle.

(4) Explosives and detonators shall not be transported in the same vehicle at the same time.

(5) No person other than the driver and his helper (not below 18 years of age) shall ride on a mechanically propelled vehicle. The vehicle loaded with explosive shall not be left unattended.

Before unloading or left standing the engine of a vehicle shall be stopped and the brakes shall be set securely. The speed of vehicle shall not exceed 25 km./hour. The vehicle shall not be taken into garage or repair shop and shall not be parked in a congested place.

The vehicle transporting explosive shall not be refused except in emergencies when engine shall be stopped.

No trailer shall be attached to a vehicle carrying explosive.

(6) The vehicle used for the transport of explosives shall be inspected once in every 24 hours by a competent person to ensure that :

(a) fire extinguishers are filled and in place ;

(b) the electric wiring is well insulated and firmly secured ;

(c) the chasis, engine and body are clean and free from surplus oil and grease ;

(d) the fuel tank and feed lines are not leaking ; and

(e) lights, breaks and steering mechanism are in good working order.

A report of every such inspection shall be maintained.

(7) All operations connected with the transport of explosives shall be conducted under the personal supervision of a foreman solely placed in charge of blasting operations at the mine.

(8) The blaster shall search every man engaged in the transport and use of explosives and shall satisfy that no person so engaged has in his possession any cigarette, biri or other smoking apparatus or any match or any other apparatus, capable of producing a light, flame or spark.

Q. 34. *What are the necessary precautions in opencast mines during firing shots.*

Ans. *Precautions—*

(1) The shot firer shall give sufficient warning by efficient signals over the area failing within the radius of 300 metres from the place of firing and shall also be ensured that all persons within this area have taken proper shelter, before charging or firing the shots.

(2) Shots shall not be fired except during the hours of day light or until adequate artificial light is provided. All holes charged on any one day shall be fired on the same day.

(3) As far as practicable the shot firing shall be carried out either between shifts or during the rest interval or at the end of work for the day.

(4) During the approach and progress of an electric storm the following precautions shall be taken :

(a) no explosive, particularly detonators shall be handled.

(b) if charging operations have been taken, the work shall be discontinued until the storm has passed.

(c) if the blast is to be fired electrically all exposed wires shall be coiled up and, if possible, placed in the mouth of the holes, or kept covered by something other than a metal plate.

(d) all wires shall be removed from contact with the steel rails of a haulage track so as to prevent the charge being exploded prematurely by a local strike of the lightening.

MISCELLANEOUS

Q 35. *What is slurry explosive ? Give the names of its basic ingredients. What are the characteristics of this explosive.*

Give some examples of permitted slurry explosive for use in our mine.

Ans A slurry explosive may be said as a saturated aqueous ammonium nitrate and sodium nitrate solution with excess of solid ammonium nitrate and sodium nitrate oxidizers dispersed within it along with an appropriate fuel and sensitizer. The whole solution is thickened and maintained in a colloidal phase by adding guar gum and gelled by certain cross-linking agents.

Basic ingredients—

(1) *Oxidizers*—Ammonium nitrate, Sodium nitrate, Potassium nitrate, Nitric acid etc.

(2) *Fuels*—Sulphur, Coal, Ethylene glycol, Fuel oil, Paraffins etc.

(3) *Sensitizers*—TNT, Nitro compounds, Aluminium etc.
(4) *Thickeners or Gelling agents*—Guar gum, Synthetic Polymer.
(5) *Cross-Linking agents*—Boron compounds, Antimony compound etc.
(6) *Stabilizers*—Di-ammonium Phosphate, Zinc chromate etc.
(7) *Water.*
(8) *Air bubbles* for perfect slurry formation.

Characteristics—

(1) By adjusting the ingredients, slurries can be formed of densities varying from 0·95 to 1·6 to give high and low velocity of detonation.
(2) If carefully formulated produce gases less of noxious.
(3) The slurries are waterproof as well as water resistant.
(4) The slurries are plastic and achieve intimate contact with the sides of the shot hole and thus are capable of transferring almost all the shock energy to the rocks.
(5) The slurries do not have any physiological ill-effect on touch.
(6) The slurries gives over all economy.
(7) The slurries can be formulated by using cheap and readily-available components.
(8) Safest explosive available at present.
(9) Need powerful booster to initiate detonation. The common boosters made out of PETN & TNT are almost 10 times as costly as the slurry.
(10) The slurries in general have a critical diameter of about 100 mm. to reduce it, sensitizer has to be of costlier variety and a close ingredient control is needed.

(11) The small diameter slurries tend to become insensitive due to release of air bubble and segregation of constituents so they should be used within 6 months of manufacture.
(12) At very low temperature the dissolved chemicals of small diameter slurries may get crystallized and thus the necessary balance for easy initiation may be disturbed. Special formulation is needed for use during low temperature period.

Examples of permitted slurries—

Permadyne (P.-3) permitted explosive for first and second degree gassy mines, permissible maximum charge in coal is 1·00 kg.

Godyne (*W*) for first degree gassy mines, permissible maximum charge in coal 0·79 kg.

Q. 36. *Describe how you will destroy old and ineffective (a) blasting explosives (b) safety fuses and (c) detonators.*

Ans. *Blasting explosives*—Gunpowder may be thrown into water, preferably into hot water where the saltpetre will dissolve, rendering the explosive harmless.

Ammonium nitrate explosives are highly hygroscopic and to make these harmless I shall scatter these explosives on damp soil. Nitro-compound explosives, gelignite, gelatine and other similar explosives shall not be destroyed more than 50 pounds at a time and a clear space of ground about 100 yards shall be seclected for the purpose to destroy these explosives. I shall lay down dry straw in a line over which I shall place the explosive cartridges with an interval of an inch between the two cartridges. Paraffin or similar oil may be poured on the cartridges so laid to help combustion.

For safety, the line of straw should be extended some distance beyond the cartridges line. I shall lit with a short length of safety fuse and retire quickly to a safe distance. The

direction of the fire should be at about an angle of 45° the direction of the wind and fire should be ignited from the weather end. Dynamite should never be burnt in larger quantities 5 pounds at a time and the wrappers must be opened and unrolled.

Safety fuses may be destroyed by burning in length in the open air.

To destroy detonators, throw into deep water by twos and threes or soak in mineral oil for 48 hours and destroy one at a time by burning.

Q. 37. *What are the chief causes of accidents from the use of explosives in the mines ?*

Ans. (1) *Not taking adequate cover.* It is essential that the shotfirer, shall before a shot is charged, stemmed or fire see that all persons in the vicinity have taken proper shelter and he shall also take suitable steps to prevent any person approaching the shot, shall himself take adequate shelter bofore firing the shots. The shot-firing cables or fuses must not be too short in length. No place in direct line with a shot shall be selected as shelter. All approaches to the danger zone shall be guarded by sentries.

(2) *Returning to the face* too soon after firing a round of shots. The fumes from the explosive may not be sufficiently diluted or a supposed miss-fire may be merely a "hang fire".

(3) *Failing to warn persons* in an adjoining place into which the shot may explode.

(4) *Tampering with miss-fired shots.* The shotfirer may attempt to withdraw the charge without following the prescribed manner of relieving hole may be drilled too near the miss-fired charge or in a direction not parallel to the original hole, so striking the detonator or charge and exploding it.

(5) *Carelessness while charging a shot-hole*, e. g. ramming a cartridge into a hole of insufficient size, or tamping too forcibly in the neighbourhood of the detonator.

(6) *Firing by electricity* when persons are at the shot-hole. The shot-firer may connect the cable to the exploder before connecting it to the detonator leads and leave the exploder with key or handle attached.

(7) *Carelessness in handling detonators.*

Q. 38. *What are the safe substitute for explosives ? Explain, in short, their principle of action and construction.*

Ans. The safe substitutes for explosives are some devices which are placed in shot holes in the coal in a similar way to the explosive to get down coal from the face. They eleminate most of the inherent dangers connected with the use of Conventional explosives. The most common substitute for explosives are :

(a) Cardox ;
(b) hydrox ;
(c) the hydraulic coal burster and ;
(d) air-breaker shells

Principle of action and construction

Cardox—Liquid carbon dioxide is used as disruptive medium. The liquid carbon dioxide vaporises within a fraction of a second when heated and built up high pressure inside the shell until the retaining disc ruptures when the sudden released gas breaks down the coal from the face.

It consists of a hollow tubular shell of high tensile chrome-molybdenum steel, at one end of this tube, there is a discharge cap which holds a shearing disc of soft steel in place and at the other end there is a firing cap

which contains a filling valve for liquid carbon dioxide and an electrode in the heater cage The heater cage is screwed into the inner end of the firing cap and is immersed in the liquid carbon dioxide in the shell.

Hydrox—In the hydrox, a granulated powder is used as disruptive medium. The powder consists of a mixture of sodium nitrate and ammonium chloride which when ignited react to produce common salt, water vapour and nitrogen. The gaseous products develop high pressure in the shell and ultimately rupture the shearing disc and and break down coal.

The general construction of the hydrox shell is almost similar to the cardox shell.

Hydraulic coal burster—High pressure water is used to break down coal in the face which is previously under-cut or over-cut or side-cut.

It consists of a stainless steel barrel, bored at interval to receive closely fitted plungers. The barrel is connected by a flexible tube to a high pressure pump. The pump forces water at high pressure to the backs of the plungers. A steel liner may be placed along the tops of the plungers to give uniform pressure.

Airbreaker shells—High pressure compressed air is utilised as the disrupting medium. Blasting is effected by the sudden release of only a very small volume of high pressure compressed air at each shot.

The essential equipments required for compressed air blasting are—

(a) a six-stage air compresssor at surface or in underground,
(b) Pipe-lines for conducting the compressed air to the face and
(c) Steel shells for discharging the air in the shot holes in the coal.

Q. 39. *What are the advantages of Compressed air blasting ?*

Describe the equipment used and the sequence of operations when blasting by this method.

Ans. *The advantages* of Compressed air blasting are as follows :

(1) Chance of igniting fire damp is remote.
(2) No danger of misfire.
(3) Excessive dust and fumes are eliminated.
(4) Cheaper if used extensively
(5) No detonator or explosive cartridge to get into coal wagons.
(6) No stemming required.
(7) No electrical firing equipment.
(8) The roof is less disturbed.
(9) Production of large coal is increased.
(10) The shot firer is not burdened with the equipments needed for firing with explosives.
(11) Loading can be started just after blasting.

The equipments used in this method i. e. compressed air blasting are—

(1) *A six-stage Compressor* installed either at the surface or underground.
(2) *Distribution pipes* of chrome-molybdenum steel.
(3) Connection between steel piping to shell is by means of copper tubing or wire braided rubber hose is frequently used instead of Copper tubing.
(4) A firing valve whose handle is retained by the shot-firer.
(5) *The airdox or air breaker* shells—There are three types, (a) Piston shell, (b) Receiver shell, (c) Shear strip shell.

The sequence of operations are—

(1) Drilling the shot holes.
(2) Inspect shell.
(3) Check pressure.
(4) Examine rubber hose and all face line connections.
(5) Turn on air.
(6) Connect hose to blow down valve and open valve immediately before firing.
(7) Test for firedamp.
(8) Insert shear plate in shell.
(9) Insert shell in shot hole.
(10) Give warning and post sentries.
(11) Test for firedamp and take shelter.
(12) Insert firing key and fire.
(13) Turn off shooting valve after firing and remove firing key.

Q. 40. *What steps should be taken to prevent pilferage of explosives from the mine ?*

Ans. The following steps are taken to prevent pilferage of explosives from the mine—

General :

(1) Only the persons who have been found to be entirely trust-worthy should be appointed as magazine incharge, shot firer or explosive carrier.

(2) The number of shot-firers and explosive carriers should be kept to a minimum.

(3) The senior officials should frequently have surprise checks on the amount of explosives with the carriers and shotfirers at different times during the shift.

Explosive boxes :

(4) The explosive boxes should be provided with self locking arrangement. The exploder key or any other

device may be used to open the explosive boxes. The key should be in the possession of the shot-firer.

(5) The boxes used for carrying explosive or detonators should be coloured and the colour for different shifts should be different and all boxes should be numbered serially in each colour. Each shot firer should be allotted same number irrespective of his shift.

Checking of original explosive boxes :

(6) Open the original explosive in the presence of assistant manager or other person specially authorised by the manager. The number of cartridges found in each box with their weight should be entered in a book.

Transit slips :

(7) As far as possible transit slips, explosive issue and return Voucher shall be prepared after enquiring about the amount of balance-coal left during previous shift and the number of shots required during the following shift.

Check in the Magazine :

(8) The number of explosive Cartridge and detonator issued to every shotfirer shall be entered in the transit slip and after signing, the magazine clerk shall put it inside the explosive box before locking it.

Check at the pit top :

(9) The attandance clerk or overman or foreman of the shift shall open and check every explosive and detonator box at the pit top or incline mouth who shall make entry and sign in the transit slip.

Checks underground :

(10) Once at least during the shift and at the end of the shot-firing operation, the sirdar shall count the number of cartridges and detonators left with the shotfires. The sirdar shall make an entry thereof in the transit slip and sign the same.

(11) During the shift, the overman/foreman and assistant manager shall check the boxes occasionally and sign the transit slip.

(12) At the end of the shift the overman/foreman shall check the boxes, enter the balance quantity of explosive in the transit slip and sign the entry.

Check at pit top at the end of shift :

(13) The shotfirer shall got his boxes checked by the attendance clerk or overman or foreman at the end of the shift at the pit top or incline mouth.

The attendance clerk or overman or foreman shall make the entry and sign in the transit slip after checking the boxes and the transit slip shall be returned directly to the manager by the attendance clerk or overman or foreman.

Final checks :

(14) The manager, assistant manager or any other authorised competent person shall countersign and receive the transit slips from the attendnnce clerk of overman or foreman. He shall check the entries in the slip against the entries made in the issue and return explosive registers maintained in the magazine.

(15) All the statutory explosive record books shall be checked by the manager or an assistance manager specially authorised by the manager for the purpose.

Stock checking in the magazine :

(16) Stock of explosive in the magazine shall be checked once at least in every week by the manager or an assistant manager authorised by the manager.

Q. 41. *What factors to be considered for selecting the site of surface main magazine and underground reserve station in the mine ?*

Ans. *Surface main magazine :*

(1) A safe distance to be maintained between the magazine and the dwelling houses, roads and other places, regularly visited by the persons.

(2) The magazine should be built on well drained sloping ground.

(3) There must be an approach road to the magazine throughout the year.

(4) The distance between the magazine and overhead power trahjmission line should be not less than 91 metres.

Underground reserve stations :

(1) The site for the reserve stations must not have any over hanging or prominent under cut. The roof of the place must be safe and be adequately supported. The place must be kept white-washed.

(2) The place should be kept clean and must be adequately fenced.

(3) All places lying within 18 metres from the reserve station must be free from coal dust and be treated with approved stone dust. The floor of the same zone should be particularly treated with at least 2 cm. thick layer of stone dust.

(4) No energised electric cables should be allowed to pass within the distance of 90 metres from the reserve station.

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P5 Explosive (Properties)

[Type] Trade Name - Soligex (P5)
2. Relative weight strength % - 38%
3. Relative Bulk strength - 31%
4. Nominal density g/ml - 1·20
5. Velocity of detonation - - 2000 meter per second
6. Waterproofness - Good.
7. Diam x length m.m - - 32x145 - 150 gms
32x195 - 200 gms
8. Application - - Delay blasting of coal of the solid.

Permitted Explosive use in U/g Coal mines - Nitro-glycerine Semi-gelatines manufactured by Indian Expl. Ltd.